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PREFORM OR MATRIX TUBULAR STRUCTURE FOR WELL CASING

The present invention concerns a preform or matrix tubular structure for well casing, particularly an oil well bore-hole.

In the present description and in the claims, the term "casing" will be understood as a well reinforcing tube, the term "preform" is a tubular structure that is initially flexible and is then hardened to bind tightly and remain against the wall of a well (thus constituting a casing), the term "matrix" is a flexible and retrievable structure used as a tool to expand the preform and apply it against the wall of the well before it is cured.

The term "production tubing" refers to a tube that is coaxial to a casing, and smaller in diameter, which carries the fluid produced by the well (water or oil in particular).

The centering and sealing of this tubing in the casing is accomplished by means of a hydraulically inflatable obturator, commonly called by the English term "packer."

For casing an oil well bore-hole, as well as for similar applications, flexible and curable tubular preforms have already been proposed that are put in place in the folded state—a state in which they take up little radial space—then are radially unfolded by application of an internal pressure. According to this technique, which in particular is described in the documents FR-A-2 662 207 and FR-A-2 668 241, the preform has, after radial deployment, a strictly cylindrical shape of specifically determined diameter.

After being placed in a well or a pipe, the wall of the preform is cured, for example by polymerizing said wall, which has a composite structure comprised of a resin impregnating filamentary sleeves. These sleeves ensure that the preform is radially inextensible.

According to these techniques, it is necessary to have a deployed casing diameter that is slightly smaller than the diameter of the hole to

be cased so that the wall of the hole does not change the cylindrical shape of the casing. The annular space thus formed, even if it is very small or non-existent in places, must usually be filled with a cement to complete the seal between the hole and the installed casing.

Moreover, in its folded form, the tubular preform has a radial cross section that is less than about half of its developed radial cross section, which in most cases is sufficient, but can prove to be insufficient for certain applications. The objective of the present invention, therefore, is to resolve this problem by proposing a preform the structure of which has a deformable geometry that can be applied to the walls of a hole to be cased (or of the casing to be lined) without, however, exceeding certain limits, this deformation being controlled and variable depending on the different applications.

Another objective of the invention is to propose a preform the degree of expansion of which is clearly superior to those obtained with the known devices of the above-mentioned type, the expansion of the preform being done in two stages, first by radial deployment, then by radial expansion.

To accomplish this, the invention proposes a braided tubular structure, which will be described further on, this structure also being applicable to a radially expandable matrix, that is, to a removable (and reusable) tool used to expand a preform for a well casing, whether or not this preform has the structure according to the invention.

These results are achieved, according to the invention, because the proposed tubular preform or matrix structure includes at least a braiding of flexible strands made of fibers that are interlaced with a certain amount of clearance so that the structure is capable of expanding radially while being constrained in an axial direction under the application of an overpressure inside the preform or matrix.

In one preferential embodiment, this braiding is composed of two series of symmetrically interlaced strands on either side of the generatrices of the tubular structure, that is, with respect to its longitudinal axis, the strands of each series being parallel to each other.

Preferably, each series of strands forms an acute angle with the longitudinal axis of between 10° and 30°, and is preferably on the order of 20° when the structure is in its radially contracted state, while this angle is between 50° and 70° when the structure is in its radially expanded state.

Preferably, the strands are flat, assuming the shape of bands.

The tubular preform, which is also the object of the invention, is notable in that it has a structure as described above.

In one preferential embodiment, the preform has a wall made of composite material, formed from a fluid and curable medium in which said structure is embedded, this medium being confined between interior and exterior skins made of elastic material.

As a corollary, the interior skin could be the wall of the matrix.

This material is preferably a resin that is curable, by heat setting for example.

In one possible embodiment, the exterior skin has portions that stand in relief, for example in the form of ring-shaped bulges.

Advantageously, the structure includes several coaxial tubular elementary structures that are in accordance with the invention, these different tubular structures being fitted into each other with the possibility of relative sliding.

The structure, preferably, is flexible enough to be able to be folded longitudinally on itself when the structure is in its radially contracted state.

Thus, if a preform is concerned, during its installation in the well or in the pipe, the operation is begun by unfolding the preform starting at one end in order to give it an approximately cylindrical shape, then it is radially expanded by deformation of the structure. The deployment by unfolding and subsequent expansion are accomplished by application of a fluid inside the preform.

The invention also concerns a tubular matrix with flexible and radially expandable wall, intended to be applied

radially against the inner wall of a preform before and during the curing thereof, in order to produce the casing for a well, and particularly an oil well bore-hole.

The wall of the matrix is provided with at least one tubular structure attached to an elastic support (also tubular, and impervious) and having a braiding of flexible strands made of fibers that are interlaced with a certain amount of clearance, so that this structure and its support can be radially expanded together, while being constrained in an axial direction under the application of an internal pressure, while conversely, they can be constrained radially while being extended axially under the application of an internal depression (vacuum) and/or an axial tension.

In one advantageous embodiment of a matrix according to the invention, the tubular structure is inserted between two elastic membranes, one interior and the other exterior, the assembly forming an inflatable sleeve equipped with a tube to carry fluid into the sleeve.

According to one embodiment, such a matrix is attached to the preform by means of easily breakable connecting elements, allowing the matrix to be removed after the casing operation, while leaving the casing inside the tube or pipe.

Other characteristics and advantages of the invention will appear from the description and attached drawings, which show non-limiting preferential embodiments thereof.

In these drawings:

– figures 1, 2, 3 are diagrams representing a preform or a matrix provided with a tubular structure according to the invention, this preform or matrix being represented respectively in the radially contracted state, in an intermediate state and in a radially expanded state;

– figures 1A, 2A and 3A are detail views representing the braiding of flexible strands comprising the structure, in a state of deformation corresponding respectively to figures 1, 2 and 3;

– figure 4 is a perspective view with removal of a preform according to the invention having several structures fitted inside each other;

– figure 5 is a transverse cross section, in larger scale, of the preform of figure 4;

– figures 6A and 6B are diagrammatical views of the cross section of the preform axially folded on itself, in two different possible configurations;

– figures 7 and 7' are similar views of either of the preforms in figures 6A or 6B, respectively after deployment and after radial expansion;

– figure 8 is a similar view to that of figure 2A showing a variant of the braiding method of the structure;

– figure 9 is a diagrammatical view in longitudinal cross section of a matrix and of a preform, both according to the invention, during the installation of the preform in a well, the matrix and the preform being deployed but not radially expanded;

– figure 9A is a detail in larger scale of the area of the wall of the matrix and preform referenced A in figure 9;

– figures 10, 10A, 10B, 10C and 10D are diagrammatical views intended to illustrate the different successive stages of installing a casing in an oil well bore-hole by means of a production tubing, using the matrix-preform assembly of figure 9.

– figure 11 illustrates a possible method of extracting the matrix;

– figures 12 and 12A represent the progressive inflation of a matrix during the expansion of a preform in a well.

The preform or matrix designated 1 in figures 1 to 3 has a tubular shape with a braided structure. Said structure is composed of an interlacing of two series of flat strands, or bands 10a, 10b, which are helically wound to constitute the cover of the structure. The two series are of opposite pitch, and the strands are inclined at an acute angle u

with respect to the generatrix of the tube it forms, which is cylindrical. To simplify the explanation, the axis XX' of the tube in figures 1 to 3 to taken as the reference. The two series of strands 10a and 10b are interlaced like caning, and are symmetrical with respect to the axis XX', on either side thereof.

Advantageously, the angle u is on the order of 20° (figures 1 and 1A).

Each of the strands 10 is formed from a plurality of fibers or wires, intertwined with each other, that are inextensible and have high mechanical strength. For example, these can be glass or carbon fibers having a diameter of several micrometers, or steel wire.

By way of example, the strands 10 have a width of between 1 and 6 mm, and a thickness of between 0.1 and 0.5 mm.

Preferably, the material comprising the fibers or wires that form these strands has a high coefficient of friction, facilitating the mutual sliding of the interlaced strands, and consequently facilitating the deformability of the structure.

As can be seen in figure 2A, the braiding of the two series of strands, 10a and 10b, is done with a certain amount of clearance, resulting in a loose assembly that has rhombus-shaped spaces 11 at the intersection of the two series 10a, 10b.

In figure 1, the preform or the matrix is represented in the configuration that gives it the longest possible length L1. In this state, the structure is self-locking, the edges of the different strands being pressed against each other. The preform has a minimum diameter D1.

It is possible to deform this structure, for example by applying an internal pressure, as will be seen further on.

This phenomenon is illustrated in figure 2. The angle that the strands make with the axial direction XX' can be increased, this deformation causing the above-mentioned spaces 11 to appear. In figures 2 and 2A the two series of strands 10a and 10b are in an intermediate position, the angle v being, for example on the order of 30° to 35°. This deformation

corresponds to an axial compression A of the structure, and correlatively, to a radial expansion R. The structure thus has a length L2 that is less than L1 and a diameter D2 that is greater than D1.

This deformation can continue until the state illustrated in figures 3 and 3A is reached, in which the structure will again lock itself with the strands comprising the braiding pressed against each other as represented in figure 3A. Preferably, the braiding is determined so that this locking is done when the angle w formed by the strands with respect to the axial direction is between 50° and 70°. The structure then has a minimal length L3 and a maximum diameter D3.

This deformation, of course, is reversible, and by pulling axially on the ends of the structure represented in figure 3, it is possible to make it return to the state in figure 1.

The braiding represented in figures 1A to 3A is a simple braiding in which a strand 10a passes alternatively above and below a strand 10b, and vice versa. Obviously other methods of braiding can be considered, such as the one represented in figure 8 for example. According to the latter method, each strand 10a passes successively above and below two strands 10b, and vice versa.

It should be remembered that the structure represented in figures 1 to 3 is purely diagrammatic, intended to explain the deformability phenomenon of the preform or matrix.

Figure 4 shows a preform 1 that can be used in industrial applications. It is composed of several deformable tubular structures such as have just been described, in this instance four coaxial structures 3a, 3b, 3c and 3d with smaller and smaller diameters, fitted into each other. In practice, a greater number of structures fitted together, such as 10, can of course be used. They are confined between two skins made of elastic materials, for example an elastomer, one exterior skin 4 and the other interior skin 5. The wall of the matrix could be used as said interior skin. They are impregnated with the fluid but curable medium, for example a

heat-setting resin, held between the two skins 4 and 5.

The capability of the skins 4 and 5 to be deformed is chosen so as to be compatible with that of the braided structures 3, because they are all deformed simultaneously and with the same amplitudes.

Due to the fluidity of the medium 30 and the flexibility of the structures 3a to 3d, which can slide freely with respect to each other, the preform can be folded longitudinally on itself. Figures 6A and 6B show two possible methods (non-limiting) of folding, respectively in U-shape and snail (spiral) shape. As a result of said folding, the preform can be given a transverse cross section that takes up very little radial space. By unfolding it, the preform can be deployed to give it the cylindrical shape represented in figure 7. Then, for example by applying an internal overpressure, the preform can be radially expanded by deformation of each of the concentric structures 3a, 3b, 3c and 3d by application of the phenomenon previously described.

Figure 9 represents a preform similar to the one just described, associated with an expansion tool intended to provide for the installation of it in a well, which tool hereinafter is called matrix.

The preform 1, represented in the infolded but not expanded state, includes—as already explained—a medium 30 of heat-setting resin that occupies the annular space situated between two skins made of elastic material, one exterior 4 and the other interior 5 or 71 (of the sleeve 7). In this space there are also several concentric, tubular, deformable structures formed by braided bands 3.

The matrix—referenced 6—includes a tubular sleeve 7 closed at its upper and lower ends by plugs 60 and 61, respectively.

The upper plug 60 has a tube 8 passing through it that has holes 80 which, like its free end, open into the interior of the sleeve 7. Appropriate means—not represented—allow a liquid under pressure to be introduced by the tube 8 inside the sleeve 7, via a flexible conduit.

This liquid can be taken from the surface. In one variant of execution, the liquid (mud, oil, etc.) present in the well can be used by introducing it into the matrix by a pump with which said matrix is equipped.

The wall of the sleeve is composed of two elastic membranes, made of an elastomer material for example, one interior 72 and the other exterior 71. Between the two membranes there is a tubular structure of braided strands as previously described, referenced as 70. In one variant, several concentric structures can be provided, fitted into each other as is the case for the preform.

The length of the sleeve 7 is greater than that of the preform 1. End plugs 60, 61 are secured—by gluing, for example—in the ends of the interior membrane 72.

The sleeve 7 is attached by its outer membrane 71 to the preform 1 by means of end collars 73, 74. These collars have rupture zones 730, 740 respectively. The collars 73 and 74 form seal rings between the preform and the sleeve 7 that comprises the matrix 6.

The interface between the outer membrane 71 of the sleeve and the interior skin 5 of the preform is treated, for example by coating with silicone, so that there is little adhesion between these two elements.

In one embodiment, the interior skin can be omitted.

Preferably, as can be seen in the detail in figure 9A, the outer face of the exterior skin 4 of the preform has bolsters 40 [*sic*]. For example, these are ring-shaped bulges separated by cavities 41 that are also ring-shaped. The function of these bolsters is to facilitate the seal with the wall of the well, and to preserve a prestress and a certain flexibility after curing.

Figures 10 and following illustrate the operation of casing an oil well bore-hole through a production tubing by means of the preform 1 and the matrix that have just been described.

P designates the wall of the well, and the reference 9 designates the production tubing of the well, this tubing being held and centered by a hydraulic obturator or "packer" 90.

By way of example, the inside diameter of the tubing 9 is 60 mm, while the average diameter of the well is on the order of 180 mm. The preform is inserted, being folded on itself in snail-like form for example (see figure 6B) so that the largest dimension of its transverse cross section is less than the inside diameter of the tubing 9. This largest diameter is for example on the order of 55 mm. The preform is then lowered, along with the tube 8, to the desired level inside the well. The preform 1 is then deployed, causing it to take on a cylindrical shape. Its outside diameter is then 90 mm. This is achieved by introducing a fluid, such as water under pressure, into the sleeve 7 via the tube 8.

This arrival of fluid is symbolized by the arrows f in figure 10A.

The pressure of the fluid is then increased, as illustrated by the arrows f' in figure 10B. This produces the radial expansion of both the sleeve 7 and the preform 1 by deformation of the braiding as was described with reference to figures 1 to 3.

Of course, at the same time this radial expansion occurs, a reduction is observed of the length of the preform and of the matrix. It thus reaches a diameter of 180 mm.

The preform is therefore applied tightly against the wall P of the well. The degree of expansion depends on the needs, that is, on the roughness of the wall. Herein is an essential difference compared to the known flexible preform device, the radial expansion of which can only be done according to a well defined diameter. The preform therefore adapts to the configuration of the well it encounters. This is facilitated even more by the presence of the bolsters 40 [*sic*], which ensure the anchoring and seal.

The wall of the preform is allowed to cure by introducing and circulating a hot fluid (and under pressure) in the

sleeve 7. When the polymerization is completed, the fluid contained in the sleeve is removed by suction, which causes the radial retraction of the sleeve, as illustrated in figure 10C.

By pulling upward on the tube 8, it is then possible to remove the assembly from the matrix by breaking the rupture zones 730 and 740.

The sleeve 7 is elongated when radially retracted, and it is possible to extract it through the tube 9.

What was formerly the preform, now hardened, constitutes a casing element of the well.

Such casing can be used with or without cement, depending on the ground conditions encountered.

When positioning the preform in the well, it is obviously necessary to take into account its reduction in axial length, which will occur during the operation.

The extraction method illustrated in figure 11 does not require the application of a vacuum inside the matrix.

Indeed, as a result of the braided structure, under the effect of the pull F' exerted on the matrix, said matrix progressively shrinks in the radial direction, from top to bottom, pulling away from the casing 1 (already cured).

The reference 7a designates the portion of the matrix already shrunk and detached from the casing, the structural strands of which form the angle u.

The reference 7b designates the expanded portion, the strands forming the angle w.

Figures 12 and 12A represent an expansion of the matrix 7 and of the preform 1 which is done progressively, from bottom to top, an inflation liquid being introduced via the tube 8 into the lower part of the matrix. The progression of the inflation can be achieved, for example, by enclosing the preform and the matrix (in folded state) in a cover that can be torn longitudinally from bottom to top.

It goes without saying, of course, that the braided deformable structure according to the invention can be implemented with preforms the installation of which does not make use of inflation matrices using such a structure, and vice versa.

In one possible embodiment of the structure, certain fibers of at least some of the strands (and advantageously of all of the strands) are replaced by wires that conduct electricity, allowing the heating of the preform or the matrix, for the purpose of polymerizing the matrix when they are connected to a source of current.

This is particularly beneficial for a matrix (reusable), the electrical connections at the two ends of the structure not presenting any particular difficulties.

CLAIMS

1. Preform or matrix tubular structure for casing a well, characterized by the fact that it includes at least a braiding of flexible strands (10, 70) made of fibers (100) that are interlaced with a certain amount of clearance so that the structure is capable of expanding radially while being constrained in an axial direction under the application of an overpressure inside the preform (1) or matrix (7).

2. Tubular structure according to claim 1, characterized by the fact that said braiding is composed of two series of strands (10a, 10b) that are interlaced symmetrically with respect to the longitudinal axis (XX') of the tubular structure, the strands of each series being parallel to each other.

3. Tubular structure according to claim 2, characterized by the fact that when it is in its radially contracted state, each of said series of strands (10a, 10b) forms an acute angle (u) with the longitudinal axis (XX') of between 10° and 30°, and is preferably on the order of 20°.

4. Tubular structure according to claim 2 or 3, characterized by the fact that when it is in its radially expanded state, each of said series of strands (10a, 10b) forms an acute angle (w) with the longitudinal axis (XX') of between 50° and 70°.

5. Tubular structure according to any of claims 1 to 4, characterized by the fact that the said strands (10, 70) are flat, assuming the shape of bands.

6. Tubular structure composed of several elementary structures according to at least one of the preceding claims, that are coaxially fitted into each other.

7. Tubular structure according to any of the preceding claims, characterized by the fact that it is flexible enough to be able to be folded longitudinally on itself when the structure is in its radially contracted state.

8. Tubular structure according to any of claims 1 to 7, characterized by the fact that certain fibers of at least some of the

strands comprising the braiding are replaced by wires that conduct electricity to allow the preform or the matrix to be heated by the Joule effect when they are connected to a source of current.

9. Radially expandable tubular preform (1), for casing a well, characterized by the fact that it has a structure in accordance with any of the preceding claims, and that it has a wall made of composite material, formed from a fluid and curable medium (30) in which said structure is embedded, this medium being confined between interior (5) and exterior (4) skins made of elastic material.

10. Preform according to claim 9, characterized by the fact that said material (30) is preferably a resin that is curable, by heat setting for example.

11. Preform according to claim 10, characterized by the fact that the said exterior skin has portions (40) that stand in relief.

12. Radially expandable tubular matrix (6), used to radially expand a preform (1) to form the casing of a well (P), characterized by the fact that it has a structure that conforms to any of claims 1 to 5.

13. Matrix according to claim 12, characterized by the fact that the said tubular structure (70) is inserted between two elastic membranes, one interior (72) and the other exterior (71), the assembly forming an inflatable sleeve (7) equipped with a tube (8) to carry fluid into the sleeve.

14. Matrix according to claim 13, characterized by the fact that it is attached to the preform (1) by means of breakable connecting elements (73, 74).

15. Tubular matrix with flexible and radially expandable wall, intended to be applied radially against the inner wall of a preform before and during the curing thereof, in order to produce the casing for a well, and particularly an oil well bore-hole, characterized by the fact that its wall is provided with at least one tubular structure attached to an elastic support and having a braiding of flexible strands (70) made of fibers that are interlaced with a certain amount of clearance, so that this

structure and its support can be radially expanded together, while being constrained in an axial direction under the application of an internal pressure, while conversely, they can be constrained radially while being extended axially under the application of an internal depression and/or an axial tension.

[see original for figures 1-12A]

INTERNATIONAL SEARCH REPORT

[see original for English]

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AFFIDAVIT OF ACCURACY

I, Kim Stewart, hereby certify that the following is, to the best of my knowledge and belief, true and accurate translations performed by professional translators of the following patents from French to English:

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